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REVIEW

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Impact of Climate Change on Fisheries and Food Security: A Comprehensive Review

R. Agnishwaran*[1] | M. Hariharan[2] | Nithya Quintoil M[1] | A. Varun[2]
Bhanu Rekha V.[1] | Ajay Kumar V. J[1]

[1]Department of Veterinary Public Health and Epidemiology, Rajiv Gandhi Institute of Veterinary Education and Research, Kurumbapet, Puducherry, India.
[2]Department of Livestock Production Management, Rajiv Gandhi Institute of Veterinary Education and Research, Kurumbapet, Puducherry, India.

Correspondence
R. Agnishwaran, Rajiv Gandhi Institute of Veterinary Education and Research, Kurumbapet, Puducherry, India.
Email: dr.agnishwaran17@gmail.com

Conflict of Interest

The authors declare that the manuscript was formulated in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Authors Contribution

All authors listed have made a substantial, direct, and intellectual contribution to the work, and approved it for publication.

Abstract

The Fisheries are vital for global food security. Its demand keeps on increasing due to increased world population and urbanisation. Many individuals rely upon them economically and for their food and, in current situation where food insecurity and poverty are becoming more prevalent, the need for development in fisheries play a significant role in ensuring a good quality of life. Food insecurity among vulnerable populations is increased by decreasing catches and harsh weather events, especially in developing nations where fisheries play a significant role. A key idea in guaranteeing a good standard of living is sustainable development, which highlights the necessity of addressing environmental issues while promoting economic progress. This article examines fish population impacts of climate change, both immediate and long-term. The impact of climate change on fishery communities from a socio-economic perspective is examined in detail, including how it may affect food supply, livelihoods, coastal ecosystems, and health concerns. The problems with food security brought on by modifications to aquatic environments as a result of worldwide warming are also covered in this, emphasising the indirect advantages of fisheries in terms of employment and the need for mitigation and adaptation measures to get past the challenges posed by changes in the climate.

KEYWORDS

Vulnerable-populations, environmental, socioeconomic, marine-ecosystems, adaptation, mitigation

INTRODUCTION

Fisheries contribute to a substantial portion of the world's food security: an estimated range of above 59 million people rely on the aquaculture sector and fisheries that are captured for their food and income, and additionally above 3 billion individuals count on fish to supply at least 20% of their average daily intake of animal-based protein (FAO, 2018). Given that seafood from both livestock and plants is a major source of vital nutrition, like essential polyunsaturated fatty acids (PUFA), such as omega-3. Seafood intake is especially important in low-income parts of the world (Lund, 2013). In a world where food scarcity and poverty are becoming more prevalent, the notion of sustainable development may play a significant role in guaranteeing a high standard of living. Sustainable growth has been predominantly regarded as the internationally recognized political, legal, and moral answer to important global concerns concerning the environment and development (Can, 2023). Fish food plays a crucial role in many developing and developed nation's food security, including captured and cultured marine fisheries. This plays a vital role in poverty reduction and improving the economy throughout the region. Due to the nearly complete depletion of marine fisheries resources, coastal aquaculture growth has been promoted as a means of providing certain countries with the essential protein-rich foods, revenue, job opportunities, and export income (Funge-Smith, 2005). The core sectors of capture fisheries and aquaculture engage up to 60 million people worldwide. Many more, particularly women, work in adjacent fields including fish handling, processing, and sales (FAO, 2020). Most of these jobs are held by small-scale fishers and aquacultural farmers in the Global South, who tend to gather a variety of species from tiny boats close to the ocean. These small-scale companies produce the majority of their fish for local markets and home use, giving rise to a valuable supply of micronutrients and a favoured source of protein in local cultures. In parts of the Global North where fishing is a major industry, fisheries are also essential to livelihoods and food security (Belton, 2014). Small native fish species, which are frequently overlooked in the advancement of aquaculture and fishing, can play a crucial role for lower-income households (Thilsted et al., 1997). Programmes can also be modified to accomplish specific goals like reducing dietary mineral and vitamin deficits. (Roos et al., 2007). But every species won't have the same nutritional content, and cooking and post-harvest handling techniques can affect food value (Gomna and Rana, 2007). However, selling little quantities of fish products as food on the streets or in marketplaces, as well as using entire small fish in stews, all provide significant nutritional benefits for lower-class homes. (James, 2013).

CLIMATE CHANGE AND FISHERIES

Climate is one significant environmental factor which regulates biodiversity. Climate change affects ecosystems in a number of ways. For example, animals may be compelled by warming temperatures to migrate to higher elevations or altitudes where the weather is more conducive to their survival. In a comparable way, as ocean levels rise, saltwater intrusion into freshwater ecosystems may force several notable species to relocate or go extinct, removing crucial predators as well as prey from the existing food chain (US EPA, 2016). Concerns regarding how climate change may affect marine ecosystems and fisheries are growing. In addition to the numerous stresses that fish populations currently face (such as contamination, disturbances, lost ecosystems, fish diseases, and invasive species), there is also the

additional strain of climate change which plays a predominant role. This suggests that while assessing the effects of climate change, other anthropogenic causes, which often have more profound and immediate impacts–must be taken into account (Brander, 2010).

Impacts of climate change on fish production

Fish populations have been impacted by the changes in the climate in both direct and indirect ways. Growth, reproduction capability, mortality, and distribution are all affected by direct impacts that impact physiology and behaviour. Indirect influences change the layout, efficiency, and overall composition of the marine ecosystems on which fish rely for food. However, a wide range of other variables, such as fishing, biological relationships, and other environmental variables unrelated to climate, can potentially have comparable impacts. These other variables should be assessed as well, and the degree of confidence in the identification ought to be indicated when a climate change is attributed (Brander et al., 2003 & Beaugrand et al., 2002). Changes in the climate will affect fishery productivity as a result of changes in:

- Winds
- Water temperature
- Dissolved oxygen
- Rising ocean acidity

Fisheries output has increased and according to projections of temperature changes and growth rates related to climate change, must progress to rise in some high-latitude locations as a result of warming and declining glacier cover (MacNeil et al. 2010). However, production is expected to drop in low-latitude locations due to decreased mixing of the water in the gradient with vital vitamins and minerals, increased heat, and damages induced by acids of important ecosystems, particularly coral reefs (Pratchett et al. 2008; Brander 2007). Stressors unique to climate change will differ in intensity and direction depending on the aquatic system. Fisheries and aquaculture are under complicated impact from climate change stress factors, which endangers fish productivity and community livelihoods. It is also anticipated that there would be a broad spectrum of effects on fisheries from climate change (Deepananda, 2012). It is critical to realize that all of the documented impacts of warming temperatures on fish at different levels of biological structure are due to physiological alterations at the genetic, cellular, and biotic levels (living thing, people, society and the environment), and that the responses specific to a species will be the foundation for the eventual causes of the increasing temperature levels at the ecological level. Consequently, interactions between species differ from those occurring inside communities. To confidently estimate the consequences of global warming on various species of fishes from marine origin and to separate the synergistic effects of fishing pressure on such populations, correlational knowledge of this kind is required (Portner and Peck 2010).

The Interplay of Climate Change and Algal Blooms in Fisheries Decline

Aquatic ecosystems, human health, the economy, and water quality can all be severely impacted by harmful algal blooms, such as those caused by

- Red tides
- Blue-green algae, or cyanobacteria.

Changes in the climate causes increase in atmospheric temperatures which may result in an increase in water temperature as well. Conditions that favour algal blooms can arise from higher water temperatures and increased nutrient discharge from rainwater (US EPA, 2023) and studies have shown that blooms can spread due to abrupt rise in nutrients like phosphorus and nitrogen, which frequently appear from agricultural fertilisers (Cressey, 2017). Harmful algae blooms have a greater impact on the aquaculture sector than on wild captured fisheries (Trainer et al., 2020). This is because cultivated species are unable to relocate from areas where harmful algal blooms are occurring, and they may perish from toxic substances or oxygen deprivation in water, this occurs frequently in estuaries or coastal waters where aquaculture operations are also being conducted. There is a strong correlation between the occurrence of toxic algal blooms and the aquaculture across the globe (Hallegraeff et al., 2021).

Impact of ENSO (El Niño Southern Oscillation) on aquaculture and marine fishing

Fishermen over South America first noticed the El Niño phenomena in the 1600s when they noticed an odd warming of the oceans current in Peru. The term translates to "little boy" or "Christ child" in Spanish language, which was selected in accordance with the timing of these warm-water occurrences, which usually occurred in December. When Peruvian scientists examined the El Niño phenomena for the first time, they thought its occurrence was a local event (Grove and Adamson, 2018). Tropical species migrate northward during these occurrences, and native fish species may either collapse or migrate towards the south (Chavez et al., 2008). Heavy rainfall brought on by the unusual warm water evaporating produces damage to infrastructure, agricultural crops, and property in addition to perhaps causing a flower bloom in the coastal desert. This phenomenon was a most notable interannual variation of the tropical climate system, which influences weather patterns all across the world. This occurrence was a particularly noteworthy interannual change of the tropical climate system, which affects global weather patterns. To illustrate, severe flooding occurs in Peru and Ecuador, whereas drought and frequent forest fires occur in Indonesia and northern Australia (Bertrand, A., 2020). During ENSO of 1997/98, Migration in the northern ranges of twenty-nine genera of tropical fishes found in the eastern Pacific were seen in the oceans of southern California (Lehodey et al., 2020). In 1998, fisheries around Pacific region of Mexico got reduced by thirty percent as a result of these modifications.

- The year that California's fisheries declined to 47% less fish and invertebrates than they had in 1997 also saw a decline in many other species, including market squid (Loligo opalescens), red sea urchin (Strongylocentrotus franciscanus), chinook salmon (Oncorhynchus tshawytscha), and many others.
- In the meantime, there was an increase in ridgeback prawn (Sicyonia ingentis), spot prawn (Pandalus platyceros), and a few demersal fish (Arntz et al., 2006).

SOCIO-ECONOMIC IMPACTS ON FISHING COMMUNITIES

Aquatic and marine ecosystems and the human cultures that rely on aquatic fisheries are being impacted by environmental climate change (Perry, 2010). But historically, the majority of studies on fisheries, climatic variability, and change have concentrated on recording patterns and oscillations in fish distribution and abundance (Glantz, 1992). Variations in oceanographic conditions, precipitation patterns, and water temperature can have an immediate effect on the people whose livelihoods depend on those ecosystems. In addition to disrupting land-based infrastructure and fishing operations, extreme weather events can also affect fisheries output variations and other natural resource availability, which can affect fishing community's livelihood (Coulthard, 2008; Iwasaki, 2009).

- Important coastal habitats may be reduced or degraded in coastal zones due to restoration of land for agriculture or excessive harvesting, variations in the sediment and pollution loading from lake and river basins, as well as potential reductions in the habitat of mangrove forests due to increasing sea levels (Ellison, 2008).
- Variations in food availability and the cost brought on by weather-related disruptions can place an additional pressure on family and community health.
- The risk of hunger and undernutrition for group of people who heavily depend on fishes as a protein source along with the dietary alterations (loss of protein from a fishery source) are some of the probable implications in a condition of decreasing availability of fish owing to events due to climatic changes.

This is especially important for the Asian countries including the African nations, as fish is their primary source of animal protein (Allison, 2009). Climate fluctuation and change have a great negative effect on several aspects of capital of the peoples, such as food security and safety at sea. The greatest impact that extreme weather events may have on human capital is often the loss of life, which affects not only the members of the household who survive but also has the potential to disrupt social and economic institutions and activities that take place outside of their immediate circle (Westlund, 2007). In South Asia and other regions of the world, fishing is a vital economic industry (Srikanthan, 2013). Those whose only source of income is fishing are directly impacted by climate change. The level of extent to which the fishery and aquatic farming-based economic structure is vulnerable and is unable to withstand the negative outcomes of the changes in the climatic conditions is the level susceptibility of fishing and aquaculture related systems towards variations in the climate and change (IPCC, 2007). Households in minor fishermen communities engage with a range of fishery and aquaculture related operations, including fishing, processing fish after catching, selling, and manufacturing the equipments for fishing (Sakib, 2020).

Fishing is prevalent livelihood activity with high level of risk because of

- The resource's migratory nature
- The oceans adverse climate
- The short shelf life of the seafood (MRAG, 2011).

Numerous fatalities are a direct result of climatic shocks like cyclones and floods. Over 100,000 people have died as a result of climate disruptions in Bangladesh and other developing nations. A large number of them were fisherman, or their friends and family members. Additional consequences include the physical injuries (Badjeck et al., 2010).

FOOD SECURITY CHALLENGES

Fisheries of marine and aquaculture origin contributes to the food security indirectly by increasing the jobs and money for food purchases. In addition to providing direct sources of protein, critical fatty acids, and minerals (McClanahan, 2015). Due to rising levels of greenhouse gases due to anthropogenic factors, particularly Carbon dioxide emissions, tropical marine fisheries are becoming more and more susceptible to alterations in the biological, geochemical and physical characteristics of the sea, such as increased temperature leading to warming of sea, increase in the sea level, reduced oxygenation, acidification, and altered concentrations of the essential nutrients (Portner, 2019; Lam, 2020). The majority of those who are directly employed as fishers and fish farmers are manual and minor level producers, with the majority located in Asia (Barange, 2018). The discussion of how vulnerable the seafood is to climate change is now rarely discussed at the national and international levels, despite the statement that many animals' biology, ecology, and chemical pathways are already being impacted by the phenomenon. Seafood security is negatively affected by unsatisfactory food safety standards that make food unsuitable for human consumption, which may force people to eat lower-quality or contaminated seafood or seafood with higher bioavailability of chemical contaminants. (Marques,2010). This is why seafood security and safety are related issues.

Due to climate change, marine fish production in the higher latitude regions will rise as a response to the growth of warm water species because of global warming, which would cause fishes and aquatic species to migrate to waters with colder temperatures in order to escape seas with increased temperatures. Tropical fisheries would decline as a result of this shift. The number of fish caught would thus, significantly decrease in southern and eastern parts of Asia, Peru, southwest regions of Africa and several developing states. In contrast, the number of fishes caught in Norway and Iceland would significantly rise (Barange et al 2014). Physical, geological and biochemical pressures also affect fish and invertebrate creatures' distribution, abundance, and reproduction through ecological systems, which has a consequence on marine fishing industry productivity both directly and indirectly (Laffoley & Baxter., 2016). Due to fish species shifting, the poleward movements in fish will also cause simultaneously poleward adaptations in jobs, capture, and value. Several tropical countries with marine ecosystems and islands that depend on fishery for nutrition, animal protein, income, lives may suffer negatively affecting their food security (Fig.1) (Golam, 2017).

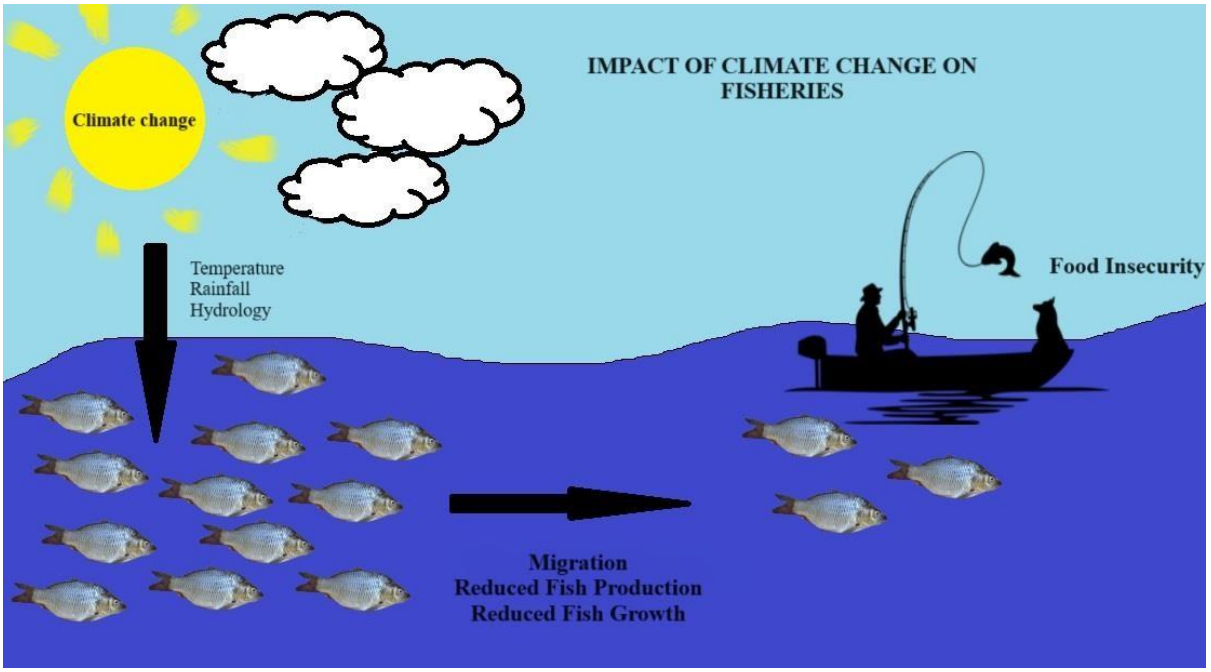

Fig.1: Impact of Climate Change on Fisheries and food security (Source: Cheung et al., 2013)

MITIGATION AND ADAPTATION STRATEGIES

In natural or human systems, adaptation is a reaction to current or anticipated climatic stimuli, that minimizes the consequences or takes advantage of the circumstances (Kibria et.al 2016). Fishermen who will be facing the negative effects by climatic change can adapt their operations and use scientific and technology advancements to help their industry (Pullin and White 2011). Other techniques for adaptation might include

- Shifting the target species
- Increasing effort or fishing power
- Gaining access to better value markets
- It could also involve leaving the existing fishery and diversifying the income source for their livelihoods (e.g., switching from marine fishing practices to the aquaculture of fishes or integrated agriculture of crops and aquaculture farming practices) (Kibria, 2013).

A variety of measures to address the fluctuation of fisheries, including shifting fishing efforts to various species in different years, switching fishing ports and regions, revising the harvest quota (Stokes and Howden, 2008). In order to maintain environmental services at their best in spite of climate change various adaptations are supposed to be made. Ecological and environmental related adaptations strategies depend on the administration, operations, protection, and rehabilitation of fish environments and stocks availability of fishes (Moosavi, 2017). Coastal infrastructure is frequently designed as part of built-environment adaptations (Forzieri et al., 2018) to reduce obstacles regarding the relocation of mangrove forests and seagrass vegetation habitats (Bell, 2018). Executions and strategies that promote community-based, climatic related responses to preserve sustainability within current community based and socialist systems are examples of policy-based adaptations (Thorne, 2017).

Some of the steps that can be taken to construct flexibility to climate change in tropical fishery systems via productive social and people related fishery and aquaculture management includes Promoting multi-disciplinary alliance such as:

- Providing knowledge needed to the participants on climate induced hazards to fish ecosystems, fish stocks availability.
- Keeping an eye out for the influence of changes in climate on the larger fishery and aquaculture system.
- Allocating funds to support implementation of an integrated approach to fisheries management (Heenan, 2015).

The marginalization and food security crisis are those that are typical of the poor who depend solely on marine can be prevented by frameworks, decisions, rights to access, markets, and governance and managemental systems that work well to coordinate and make assurance for the benefits of local and international trade (Cinner et al. 2012). A diagnostic method is necessary to evaluate possibilities for aquaculture management improvements in terms of their anticipated effect on the most reliant, food-insecure people (Ratner and Allison 2012).

FUTURE PERSPECTIVES AND RECOMMENDATIONS

Researchers must expand their current multidisciplinary collaborative framework, that is confined to world marine based subjects and its applied sciences, the environment, and financial affairs, in order to understand societal impacts on fisheries due to changes in the climate and to guide beneficial and successful adaptive measures. This framework should comprise the study over the geographical regulations on marine ecosystems, information, data, content accumulation, interactions, individual responsibility, and aquatic behaviours (Allison, 2015). Future studies in these areas will enhance the awareness of the climate changes negative causes in the scientific policy organizations, also in fishing communities. This will enable them to incorporate the understanding with their systems of values, benefits, and abilities for adaptation (Cinner et al., 2018). People's ability to create, assimilate, and understand new knowledge about adaptation strategies, living with insecurity, and managing it is reflected in their capacity to learn (Badjeck et al., 2010). For instance, fishermen will need to adapt to new fishing areas, equipment, conditions, species, technological advances, and in certain situations, new means of subsistence as a response to the climatic impacts (Berkhout, 2006).

CONCLUSION

Climate change have significant and diverse influence on fisheries and food safety, posing a wide range of issues of concern that threaten marine ecosystems and global availability on food leading to insecurity of food worldwide. The availability and distribution of fish species are known to alter as a result of major impacts on marine environments caused by rising sea temperatures, ocean acidification, and harsh weather. These changes cause economic losses for communities who depend solely over fisheries and its related industry and endanger the lives of several people globally by upsetting fishing patterns. Changes in water composition and temperature brought on by climate change may influence the number of harmful substances, pollutants, and toxic algal blooms that are present in seafood which

might result in a number of health problems if not properly monitored and addressed. Establishment of adaptive strategies into practice, such as creating marine conservation zones and managing fisheries on the basis of ecosystems, we can lessen the climates influence on fisheries and increase the resilience of marine and other related aquatic ecosystems. To protect the public's health, it is also essential to improve investigation, warning mechanisms, and surveillance systems for identifying and controlling any dangers to food safety in seafood. Governments and stakeholders can work together to secure the future of fisheries, safeguard food safety, and maintain the wellbeing of both human populations and marine ecosystems in a changing climate by prioritizing adaptive measures, funding research, and promoting international cooperation.

REFERENCES

Allison, E. H., & Bassett, H. R. (2015). Climate change in the oceans: human impacts and responses. Science, 350(6262), 778-782.

Allison, E. H., Perry, A. L., Badjeck, M. C., Neil Adger, W., Brown, K., Conway, D.,.....& Dulvy, N. K. (2009). Vulnerability of national economies to the impacts of climate change on fisheries. Fish and fisheries, 10(2), 173-196.

Arntz, W. E., Gallardo, V. A., Gutiérrez, D., Isla, E., Levin, L. A., Mendo, J.,.....& Wolff, M. (2006). El Niño and similar perturbation effects on the benthos of the Humboldt, California, and Benguela Current upwelling ecosystems. Advances in geosciences, 6, 243-265.

Badjeck, M. C., Allison, E. H., Halls, A. S., & Dulvy, N. K. (2010). Impacts of climate variability and change on fishery-based livelihoods. Marine policy, 34(3), 375-383.

Barange, M., Bahri, T., Beveridge, M. C., Cochrane, K. L., Funge-Smith, S., & Poulain, F. (2018). Impacts of climate change on fisheries and aquaculture. United Nations' Food and Agriculture Organization, 12(4), 628-635.

Barange, M., Merino, G., Blanchard, J. L., Scholtens, J., Harle, J., Allison, E. H., & Jennings, S. (2014). Impacts of climate change on marine ecosystem production in societies dependent on fisheries. Nature Climate Change, 4(3), 211-216.

Beaugrand, G. (2004). The North Sea regime shift: evidence, causes, mechanisms and consequences. Progress in Oceanography, 60(2-4), 245-262.

Bell, J. D., Cisneros-Montemayor, A., Hanich, Q., Johnson, J. E., Lehodey, P., Moore, B. R., ... & Wabnitz, C. C. (2018). Adaptations to maintain the contributions of small-scale fisheries to food security in the Pacific Islands. Marine Policy, 88, 303-314.

Belton, B., & Thilsted, S. H. (2014). Fisheries in transition: Food and nutrition security implications for the global South. Global Food Security, 3(1), 59-66.

Berkhout, F., Hertin, J., & Gann, D. M. (2006). Learning to adapt: organisational adaptation to climate change impacts. Climatic change, 78(1), 135-156.

Bertrand, A., Lengaigne, M., Takahashi, K., Avadí, Á., Poulain, F., & Harrod, C. (2020). El Niño Southern Oscillation (ENSO) effects on fisheries and aquaculture. In FAO eBooks.

Brander K. M. (2007). Global fish production and climate change. Proceedings of the National Academy of Sciences of the United States of America, 104(50), 19709-19714.

Brander, K. (2000). Effects of environmental variability on growth and recruitment in cod (Gadus morhua) using a comparative approach. Oceanologica Acta, 23(4), 485-496.

Brander, K. (2010). Impacts of climate change on fisheries. Journal of Marine Systems, 79(3-4), 389-402.

Can, M. F., Mazlum, Y., & Erkan, B. (2023). Is there a relationship between human development and dependence on fisheries? Oceanological and Hydrobiological Studies, 52(2), 245-257.

Chavez, F. P., Bertrand, A., Guevara-Carrasco, R., Soler, P., & Csirke, J. (2008). The northern Humboldt Current System: Brief history, present status and a view towards the future. Progress in Oceanography, 79(2-4), 95-105.

Cheung, W. W., Watson, R., & Pauly, D. (2013). Signature of ocean warming in global fisheries catch. Nature, 497(7449), 365-368.

Cinner, J. E., Adger, W. N., Allison, E. H., Barnes, M. L., Brown, K., Cohen, P. J., ... & Morrison, T. H. (2018). Building adaptive capacity to climate change in tropical coastal communities. Nature Climate Change, 8(2), 117-123.

Cinner, J.C., McClanahan, T.R., Stead, S. et al. (2012) Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. Global Environmental Change 22, 12-20.

Coulthard, S. (2008). Adapting to environmental change in artisanal fisheries–Insights from a South Indian Lagoon. Global Environmental Change, 18(3), 479-489.

Cressey, D. (2017). Climate change is making algal blooms worse. Nature.

Deepananda, K. A., & Macusi, E. D. (2012). The changing climate and its implications to capture fisheries: a review. Journal of Nature Studies, 11(1&2), 71-87.

Ellison, A. M. (2008). Managing mangroves with benthic biodiversity in mind: moving beyond roving banditry. Journal of Sea Research, 59(1-2), 2-15.

FAO. (2018). The state of world fisheries and aquaculture Meeting the sustainable development goals. Rome.

FAO. (2020). The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome.

Forzieri, G., Bianchi, A., e Silva, F. B., Herrera, M. A. M., Leblois, A., Lavalle, C., ... & Feyen, L. (2018). Escalating impacts of climate extremes on critical infrastructures in Europe. Global environmental change, 48, 97-107.

Funge-Smith, S., Lindebo, E., & Staples, D. (2005). Asian fisheries today: The production and use of low value/trash fish from marine fisheries in the Asia-Pacific region.

Glantz MH. Climate variability climate change and fisheries. Cambridge: Cambridge University Press; 1992.

Golam, K., Haroon Yousuf, A. K., & Dayanthi, N. (2017). Climate change impacts on tropical and temperate fisheries, aquaculture, and seafood security and implications-A review. Livestock Research for Rural Development, 29, 1-29.

Gomna, A., & Rana, K. (2007). Inter-household and intra-household patterns of fish and meat consumption in fishing communities in two states in Nigeria. The British journal of nutrition, 97(1), 145–152.

Grove, R., & Adamson, G. (2018). El Niño in world history (p. 81). London: Palgrave Macmillan.

Hallegraeff, G., Enevoldsen, H., & Zingone, A. (2021). Global harmful algal bloom status reporting. Harmful Algae, 102, 101992.

Harley, C.D; Hughes; Hultgren, R.A.; Miner, K.M.; Sorte, B.G.; Thornber C.J.B.; Rodriguez, C.S.; Tomanek, L.F. andand Williams, S.L. (2006). The impacts of climate change in coastal marine systems. Ecol. Lett.,9: 228 - 241.

Heenan, A., Pomeroy, R., Bell, J., Munday, P. L., Cheung, W., Logan, C., & Yasin, Z. (2015). A climate-informed, ecosystem approach to fisheries management. Marine Policy, 57, 182-192.

IPCC (2007). Climate Change 2007: Impacts, adaptation and vulnerability: Contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Cambridge University Press, Cambridge.

Iwasaki, S., Razafindrabe, B. H. N., & Shaw, R. (2009). Fishery livelihoods and adaptation to climate change: a case study of Chilika lagoon, India. Mitigation and adaptation strategies for global Change, 14, 339-355.

Kibria G, Haroon A K Y and Nugegoda D (2016) Climate change and water security: Impacts, future projections, adaptation, and mitigations. 312 p. DOI: 10.13140/RG.2.1.1848.1528/1;. ISBN: 978-93-85516- 26-9.

Kibria, G. (2013). Climate Change and Agricultural Food Production: Impacts, Vulnerabilities & Remedies. New India Publishing.

Laffoley, D., & Baxter, J. M. (Eds.). (2016). Explaining ocean warming: Causes, scale, effects and consequences. Gland, Switzerland: IUCN.

Lam, V. W. Y., Allison, E. H., Bell, J. D., Blythe, J., Cheung, W. W. L., Frölicher, T. L., ... Sumaila, U. R. (2020). Climate change, tropical fisheries and prospects for sustainable development. Nature Reviews Earth & Environment.

Lehodey, P., Bertrand, A., Hobday, A. J., Kiyofuji, H., McClatchie, S., Menkès, C. E.,... & Tommasi, D. (2020). ENSO impact on marine fisheries and ecosystems. El Niño Southern Oscillation in a changing climate, 429-451.

Lund E. K. (2013). Health benefits of seafood; is it just the fatty acids? Food chemistry, 140(3), 413-420.

MacNeil, M. A., Graham, N. A., Cinner, J. E., Dulvy, N. K., Loring, P. A., Jennings, S., Polunin, N. V., Fisk, A. T., & McClanahan, T. R. (2010). Transitional states in marine fisheries: adapting to predicted global change. Philosophical transactions of the Royal Society of London. Series B, Biological sciences, 365(1558), 3753-3763.

Marques, A., Nunes, M. L., Moore, S. K., & Strom, M. S. (2010). Climate change and seafood safety: Human health implications. Food Research International, 43(7), 1766-1779.

McClanahan, T., Allison, E. H., & Cinner, J. E. (2015). Managing fisheries for human and food security. Fish and Fisheries, 16(1), 78-103.

Moosavi, S. (2017). Ecological coastal protection: pathways to living shorelines. Procedia Engineering, 196, 930-938.

MRAG (2011) Fisheries and livelihood. Fisheries Management Science Programme (FMSP), Marine Resources Assessment Group (MRAG), and Department for International Development (DFID), London. Retrieved from: www.mrag.co.uk/ Documents/ PolicyBrief4_Livelihoods.pdf. Accessed on 25 Oct 2011.

Muir, J. F. (2013). Fish, feeds, and food security. Animal Frontiers, 3(1), 28-34.

Perry, R. I., Ommer, R. E., Allison, E. H., Badjeck, M., Barange, M., Hamilton, L., Jarre, A., Quiñones, R. A., & Sumaila, U. R. (2010). Chapter 8 Interactions between changes in marine ecosystems and human communities. In M.Barange, J.G. Field, R.P. Harris, E. E. Hofmann, R.I. Perry, & F. Werner (Eds.), Marine ecosystems andglobal change (pp.221-252).

Pörtner HO, Peck MA. (2010). Climate change effects on fishes and fisheries: towards a cause-and-effect understanding. J. Fish. Biol. 77: 1745-1779.

Pörtner, H. O., Roberts, D. C., Masson-Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., & Weyer, N. M. (2019). The ocean and cryosphere in a changing climate. IPCC special report on the ocean and cryosphere in a changing climate, 1155.

Pratchett, M. S., Munday, P., Wilson, S. K., Graham, N. A., Cinner, J. E., Bellwood, D. R., & McClanahan, T. R. (2008). Effects of climate-induced coral bleaching on coral-reef fishes. Ecological and economic consequences. Oceanography and Marine Biology: Annual Review, 46, 251-296. DOI: 10.1201/9781420065756.ch6

Pullin R and White P. (2011) Climate change and aquatic genetic resources for food and agriculture: State of knowledge, risks and opportunities. FAO Background study paper no 55. Rome, Italy. 106 p

Ratner, B.D. and Allison, E.H. (2012) Wealth, rights, and resilience: an agenda for governance reform in smallscale fisheries. Development Policy Review 30, 371-398.

Roos, N., Wahab, M. A., Chamnan, C., & Thilsted, S. H. (2007). The role of fish in food-based strategies to combat vitamin A and mineral deficiencies in developing countries. The Journal of nutrition, 137(4), 1106-1109.

Sakib, M. H., Aziz, M. T., Harun-Al-Rashid, A., Ahsan, M. R., & Afrad, M. S. I. (2020). Ecological and Socio-economic Impacts of Climate Change on Fisheries. Indian Res. J. Ext. Edu, 20(2&3), 67-74.

Srikanthan, S. (2013). Impact of climate change on the fishermen's livelihood development: a case study of village in Coromandel Coast. Journal of Humanities and Social Science, 12(6), 49-54.

Stokes C J and Howden S M (2008) An overview of climate change adaptation in Australian primary industries – impacts, options and priorities. Report prepared for the National Climate Change Research Strategy for Primary Industries. CSIRO, Australia. 346 p.

Thilsted, S.H.; Roos, N.; Hassan, N. (1997). The role of small indigenous fish species in food and nutrition security in Bangladesh. NAGA 20 (3/4): 82-84

Thorne, J. H., Choe, H., Boynton, R. M., Bjorkman, J., Albright, W., Nydick, K., & Schwartz, M. W. (2017). The impact of climate change uncertainty on California's vegetation and adaptation management. Ecosphere, 8(12), e02021.

Trainer, V. L., Moore, S. K., Hallegraeff, G., Kudela, R. M., Clement, A., Mardones, J. I., & Cochlan, W. P. (2020). Pelagic harmful algal blooms and climate change: Lessons from nature's experiments with extremes. Harmful algae, 91, 101591.

US EPA. (2016). Climate impacts on ecosystems. Climate Change Impacts. Retrieved January 7, 2023.

US EPA. (2023). Climate adaptation and harmful algal blooms, US EPA.

Westlund, L. (2007). Disaster response and risk management in the fisheries sector (Vol. 479). Food & Agriculture Org.

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